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PLATFORM MOTION CONTRIBUTIONS TO SIMULATOR TRAINING EFFECTIVENESS:

STUDY III – INTERACTION OF MOTION WITH FIELD-OF-VIEW

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NOTICE

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The objective ~~of this study~~ was to determine the effects of platform motion cueing, visual field of view (FOV), and their interaction upon learning in the simulator and as subsequent transfer of training to the aircraft for basic contact maneuvers in the T-37 aircraft. A transfer-of-training study design was used in which student pilots were initially trained in the Advanced Simulator for Pilot Training (ASPT) and subsequently evaluated on their first sortie in the T-37 aircraft. Each student received training under one of four simulator configurations: (a) full platform motion (six degrees of freedom), full FOV (300° horizontal by 150° vertical; (b) full platform motion, limited FOV (48° horizontal by 36° vertical); (c) no platform motion, full FOV; and (d) no platform motion, limited FOV. For the ASPT pretraining phase, scores from the automated performance measuring system and overall instructor pilot

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ratings were used for analysis. For the T-37 evaluation sorties, the overall instructor pilot ratings, as well as individually recorded flight parameters, were analyzed. These data provided no conclusive evidence of differential transfer effects resulting from platform motion cueing, size of the visual FOV, or their interaction. As such, these data provide support for previous findings that platform motion cueing does not significantly enhance the transfer of learning for basic contact tasks in the T-37 aircraft. It would seem that the impact of peripheral visual cues for initial acquisition is not critical. Furthermore, no convincing evidence was found indicating increased transfer using platform motion in conjunction with a narrow FOV visual scene. The major implication from these findings is that a fixed-base, limited FOV simulator configuration provides sufficient cueing for basic contact skills normally trained during Undergraduate Pilot Training.

PREFACE

This report represents a portion of the research program of project 1123, USAF Flying Training Development, Mr. James F. Smith, Project Scientist; task 112303, Exploitation of Simulation in Flight Training, Mr. Robert Woodruff, Task Scientist. This study was conducted by the Flying Training Division of the Air Force Human Resources Laboratory (Air Force Systems Command) and supported by the 82d Flying Training Wing (Air Training Command), Williams AFB, Arizona.

The authors would like to express sincere appreciation to a number of individuals without whose cooperation and assistance this project could not have been completed. The maneuver score sheets were prepared by Ms. Elizabeth P. Casey; statistical and computer support was provided by Mr. Tien F. Sun and Mr. Richard O. Greatorex; and A1C Randy Cline provided data sheet transcriptions and other administrative support. Instructor Pilot duties were performed by the following individuals from the Research Division of the 82d Flying Training Wing: Major Mike Moorman, Capt Pete Drechsler, Capt Ron Wetters, and Capt Lee Lesher. Capt Drechsler also was responsible for scheduling the students and coordinating all activities with the flight line. Dr. Elizabeth L. Martin provided many suggestions during the planning of the study and invaluable editorial support during the preparation of this report.

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PLATFORM MOTION CONTRIBUTIONS TO SIMULATOR TRAINING EFFECTIVENESS: STUDY III – INTERACTION OF MOTION WITH FIELD-OF-VIEW

I. INTRODUCTION

Currently, two major hardware issues are of concern in the design of flight simulators and the resulting training effectiveness. The first involves the degree to which simulator platform motion cueing affects pilot performance, particularly skill acquisition and its subsequent transfer to the aircraft; the dominant question concerns the extent to which motion cueing is required in the simulator to obtain effective training. The second issue involves the degree to which complex extra-cockpit visual displays benefit training and the minimum requirements for such displays to be effective.

The value of platform motion cueing to enhance simulator training effectiveness has been recently questioned. Despite research data showing improved single-axis tracking performance and improved in-simulator performance under certain conditions, there is no evidence to indicate improved transfer of learning to subsequent performance in the aircraft (Puig, Harris, & Ricard, 1978). A series of studies was initiated at the Air Force Human Resources Laboratory to determine the effectiveness of platform motion cueing for naive Undergraduate Pilot Training (UPT) students transitioning into the T-37 aircraft.

Following final acceptance of the Advanced Simulator for Pilot Training (ASPT) in 1975, a study was conducted to evaluate the contributions of platform motion to the acquisition of basic contact skills. Two groups (n=4) were trained to proficiency in the simulator and subsequently evaluated in the T-37 aircraft. No differences in either simulator or aircraft performance were obtained. Woodruff, Smith, Fuller, and Weyer (1976) conducted an exploratory study to investigate the utility of the ASPT as a full mission simulator in the basic phase of UPT. Block training was provided for Basic Contact, Advanced Contact (Aerobatics), Instruments, Navigation, and Formation Flight. Upon completion of each block of training in the ASPT, the student was assigned to an aircraft for corresponding instruction. Eight students received ASPT pretraining while a control group of eight students did not. Half of the experimental group was trained with platform motion (n=4) while the other half was not (n=4). Proficiency advancement was used for all instruction in both the simulator and aircraft. The resulting aircraft hours savings were 45% for Basic Contact, 4% for Advanced Contact, 38% for Instruments, and 13% for Navigation. No significant differences were obtained between the Motion and No Motion groups.

In a subsequent effort, Martin and Waag (1978a) addressed the same question using more rigorous control procedures and a larger sample size. Twenty-four preflight UPT students with no previous jet piloting experience were randomly assigned to one of three treatment groups (n=8): (a) Motion, (b) No Motion, and (c) Control. Those students assigned to the control group received the standard syllabus of preflight and flightline instruction. The students in the two experimental conditions received identical pretraining in the Advanced Simulator for Pilot Training (ASPT) with the exception of the presence or absence of platform motion cueing. The G-seat was not used. The simulator training syllabus consisted of 10 ASPT sorties covering instruction on a large number of basic contact maneuvers, including basic airwork (turns, climbs, etc.), slow flight, stalls, takeoffs, straight-in approach and landing, overhead pattern, and touch-and-go. Following simulator pretraining, the students were evaluated on two special aircraft sorties by research Instructor Pilots (IPs) as well as on all sorties prior to solo by their normal flight line IPs. The control group did not receive the two special data rides due to safety considerations. Evaluations in the T-37 aircraft revealed substantial transfer of training. However, with respect to the two experimental groups, i.e., Motion and No Motion, no statistically reliable differences were found for either performance in the simulator or subsequent performance in the aircraft. Within the aircraft, this finding was observed for student performance on two special data sorties at the beginning of training, as well as their performance prior to solo.

With the exception of stalls, motion cues for the training tasks were incidental or secondary [illegible] the most part. Typically, the magnitude of transfer effects expected from such incidental cu[illegible] small compared to that from primary cues. Moreover, there is not a great deal of motion cueing involve[illegible] these tasks in that the amount and/or magnitude of force cueing in the aircraft is relatively small. For this reason, it seemed necessary to extend the effort to aerobatic tasks in which motion cues are more prominent (Martin & Waag, 1978b). Thirty-six UPT students were assigned to one of three treatment groups (n=12): (a) Motion; (b) No Motion; and (c) Control. Students in the two experimental groups received five ASPT sorties covering instruction on eight aerobatic tasks. The control group did not receive any ASPT pretraining. All students were subsequently evaluated in the T-37 aircraft by their normal flight line IPs. The obtained data suggested only a modest degree of transfer. Of the eight maneuvers trained in the ASPT, only the Barrel Roll produced an overall significant transfer effect across the three groups. However, approximately one-third of the ASPT-trained vs. Control group a priori t-tests produced significant effects. In all cases, superior performance was demonstrated by the ASPT-trained groups. A comparison between the Motion and No Motion groups revealed some small, although inconsistent, performance differences during simulator training. Of those individual aircraft measures demonstrating significantly better performance by the simulator-trained groups (13 of 40), none revealed a reliable effect due to motion.

Since each of these previous studies utilized the entire ASPT field of view (FOV) (which is 300 degrees horizontal by 150 degrees vertical), it was speculated that peripheral cues may have been imparting important "motion" information. In the event such visually perceived motion cues were of sufficient magnitude, the effect of platform motion cueing possibly could be reduced. If such were the case, platform motion cueing would be expected to have a greater effect for narrow FOV visual systems, such as those used by some Air Force operational flight simulators. The present study was designed to address this question. Specifically, the objectives were to determine the effects of motion cueing, FOV, and their interaction upon (a) skill acquisition in the simulator and (b) subsequent transfer of learning to the aircraft.

II. METHOD

General Approach

A transfer-of-training study design was employed in which the students were initially trained for a fixed number of trials in the ASPT and subsequently evaluated during their first T-37 sortie. Two variables were of interest–platform motion cueing and the visual FOV. Half of the subjects flew all of their ASPT sorties with the full six-degrees-of-freedom platform motion. Each of the remaining subjects flew all of their ASPT sorties without platform motion. Half of the subjects in each of the motion conditions flew all of their ASPT sorties with the full FOV (300°H x 150°V). For the remainder of the subjects, part of the visual scene was computer "masked" to produce a 48°H x 36°V FOV. This FOV was selected because of its use in many Air Force operational flight trainers, including Air Training Command's new Instrument Flight Simulator for the T-37 and T-38. This resulted in the following four experimental groups: (a) full platform motion, full FOV; (b) full platform motion, limited FOV; (c) no platform motion, full FOV; and (d) no platform motion, limited FOV.

Subjects

The subjects were selected randomly from UPT classes 78-04 and 78-05 at Williams AFB. They were selected with the restriction of having had little prior flying experience; the range of previous flight experience was 25 to 64 hours. Sixteen subjects were selected from each class. Each student flew all of the required ASPT sorties within one of the four experimental groups.

Instructor Pilots

Four IPs from the Research Division of the 82nd Flying Training Wing (82FTW/DOR) provided the ASPT instruction and T-37 evaluation. The assignment of students to IPs was counterbalanced by having each IP instruct one student from each UPT class in each of the four experimental groups. Each IP received orientation training over a period of several days immediately before both UPT classes.

Equipment

Experimental training was accomplished in the ASPT. An overview of the ASPT aspects most relevant to the present study is presented in this section. Detailed descriptions of this device may be found in Gum, Albery, and Basinger (1975). The ASPT is equipped with two T-37 cockpits. Each cockpit has a full FOV visual display of computer-generated images, a six-degrees-of-freedom, synergistic platform motion system, and a 16-panel pneumatic G-seat on the left seat (student position).

The visual display is projected through seven 36-inch cathode ray tubes (CRTs). The capacity for displaying visual image detail is fixed and shared between the two cockpits. A highly detailed scene, such as an airport, requires 90% to 100% of the display capacity. In the present study, 100% of the visual display capacity was used for training.

The visual system uses an infinity optics display with the exit pupil located at the student's eye position, but a distorted scene from the IP position. From a normal position, the IP is unable to see the visual display immediately in front of the aircraft. The scene becomes less distorted as the IP scans laterally. If the position of the IP's head is moved nearer to that of the student, the forward-looking view of the IP is increased and the distortion is reduced.

The platform motion system is driven by six hydraulic actuators, each with a travel capability of 60 inches. The platform motion system software was designed to provide translational and rotational acceleration onset cues to the student pilot position. Excursion limits and maximum accelerations are presented in Table 1. The drive philosophy for the display of translational acceleration cues is intended to match the aircraft acceleration in magnitude and shape, whereas the display of onset rotational accelerations is driven by a cue-shaping philosophy. Some sustained acceleration cues can be simulated via platform movement with a subsystem called "gravity align" which positions the platform in an attempt to substitute for a portion of the external force vector. (The G-seat can also display sustained accelerating cues; however, the G-seat was not used in this study and will not be discussed). The motion system also includes a special effects package for displaying such cues as touchdown bump, runway rumble, aircraft buffet, speedbrake extension, and gear-down rumble.

Table 1. **ASPT Platform Motion Performance Characteristics**

Axis	Excursion	Acceleration
Forward (X)	+49 in., −48 in.	±0.6g
Lateral (Y)	±48 in.	±0.6g
Vertical (Z)	+39 in., −30 in.	±0.8g
Roll (X)	±22°	±50°/sec^2
Pitch (Y)	+30°, −20°	±50°/sec^2
Yaw (Z)	±32°	±50°/sec^2

The ASPT has the capability of real-time, automated measurement of the pilot's performance via the Automated Pilot Measurement System (APMS). Measurements can be made of pilot inputs, system outputs, and derived scores. A limited amount of this information can be displayed real-time in the cockpit via a monitor located to the right of the IP position and/or following the mission in hard copy form. The ASPT is also equipped with the capability of displaying a prerecorded demonstration of a maneuver which enables a reproduction of the entire maneuver, including visual display, motion cues, instrument readings, and rudder and throttle movements.

Two additional capabilities of the ASPT were utilized in the present study: problem freeze and reinitialization. The instructor can stop and hold the system at its current position by the use of the problem freeze feature. From this position, the IP can continue flight from the "frozen" position or return to a desired starting point by use of the reinitialization feature. Reinitialization allows the system to go to a designed position and configuration in a matter of seconds. These points are preprogrammed to correspond to optimal starting positions for most maneuvers, including cross-country positions, in the T-37 training program. The main utility of the freeze feature is in its instructional value, whereas the reinitialization is a time-saving feature which also allows for tighter experimental control over student practice.

The advanced instructor operator console (AIOS) is equipped with a Vector General monitor which has a spatial display option. This option can follow the flightpath of the simulated aircraft which can be rotated around the X, Y, or Z axis. This image can be temporarily stored and displayed following the mission for use in the debriefing.

Procedure

Cognitive Pretraining. All students viewed two sets of cognitive pretraining materials. One set was a selection from the learning center at Williams AFB. The students were required to view the material within 1 week of their scheduled, first ASPT sortie. At that time, they also viewed an audio-visual (AV) taped, safety briefing on the ASPT. Immediately prior to their first ASPT sortie, the students also viewed an AV-taped ground briefing which described the maneuvers. The verbatim text is presented in Appendix A.

IP Orientation Training. The IPs, who provided instruction, were also required to use specially prepared data cards to evaluate the students' overall performance with the following 8-point scale: 1 = unsatisfactory; 2, 3, 4 = fair; 5, 6, 7 = good; and 8 = excellent. The development and validation of these cards are presented in Appendix B. In order to familiarize the IPs in the use of the scale, practice was given by evaluating recorded demonstrations. Two demonstrations were recorded for each of the four maneuvers; one in the "good" range and one in the "fair" range. Before the first class of UPT students, each IP evaluated the eight demonstrations on 2 successive days. These evaluations were accomplished from the right seat, where the IP usually sits, and a volunteer sat in the student's seat. On each day, the IPs were shown how each of them had evaluated the respective demonstrations. During in-depth debriefings, the IPs discussed how they performed their evaluations.

ASPT Training. The ASPT syllabus of instruction is presented in Table 2. As indicated, the students first received a demonstration for each maneuver. The demonstrations had previously been recorded for

Table 2. **ASPT Sorties**

Sortie 1	Sortie 2	Sorties 3 & 4
	Takeoff	
Demonstration	Practice	Practice
Practice	Practice	Practice
Evaluation[a]	Evaluation[a]	Evaluation[a]
	Steep Turn	
Demonstration	Practice	Practice
Practice	Practice	Practice
Evaluation[a]	Evaluation[a]	Evaluation[a]
	Slow Flight	
Demonstration	Practice	Practice
Practice	Practice	Practice
Evaluation[a]	Evaluation[a]	Evaluation[a]
	Straight-In and Landing	
Demonstration	Demonstration	Practice
Practice	Practice	Practice
Practice	Practice	Practice
Practice	Practice	Practice
Evaluation[a]	Evaluation[a]	Evaluation[a]

[a]Student performance was evaluated by both the APMS and the special data cards.

playback during the study. Each demonstration contained an error which students frequently made. As part of the narrative, the subjects were instructed how to recover if they committed the error.

Following one or more practice trials, the students were measured on the last trial on each maneuver for each of the four ASPT sorties. Student performance was evaluated by the IP; it was also computer-scored using the APMS. Each student had the same IP for all four ASPT sorties.

In an attempt to reduce the inter-trial interval and to maximize the transfer of training, there were several constraints placed on the distribution of sorties in the ASPT and in the T-37. First, the T-37 sortie was to occur not more than one day after the fourth (final) ASPT sortie. Second, the third and fourth ASPT sorties were to occur on successive days. Third, at no time would there be more than 2 days separating any of the first three ASPT sorties. The schedule was maintained for 28 of the subjects. With the remaining four subjects, an ASPT equipment failure delayed the fourth ASPT sortie. This resulted in having that final ASPT sortie flown in the morning; the T-37 sortie was flown later that same day. There were no discernible differences between the data of those four subjects and the other 28 subjects.

In order to preclude the subjects in the Motion and No Motion groups from perceiving accentuated differences between treatments, all students heard the following communications at the start and end of each ASPT sortie: "motion coming up" and "motion coming down." The platform was raised and lowered, respectively, to give each student some motion sensation.

T-37 Evaluation. For the transfer to the T-37 portion of the study, the same IP who worked with the student on the ASPT flew a single sortie with that student. This was the first time that any of the students had flown in the T-37 aircraft. The students attempted to perform each maneuver in the T-37 without a demonstration by the IP. Student performance was evaluted on the same type of special data cards used for the ASPT evaluation.

III. RESULTS

ASPT Training

All students completed the four ASPT instructional sorties. Student performance was evaluated once for each task on every sortie. The occurrence of these evaluations within the training sequence is presented in Table 2. For each evaluation, two types of data were analyzed: (a) the overall IP rating using the special data cards and (b) objective scores from the APMS on the ASPT. Included in the APMS data were root mean square (RMS) deviation scores for system state outputs and RMS movement scores for control inputs on each maneuver. Specific parameters included in the data analysis are presented in Appendix C. For each parameter, analyses of variance (ANOVAs) were computed using natural log (*ln*) transformations of the raw data.

IP Ratings. The overall IP ratings for the ASPT sorties were analyzed using a split-plot factorial ANOVA design having two between-subjects factors (Motion and FOV) and one repeated measure (Trials). The results of the ANOVAs are presented in Table 3, and descriptive statistics are presented in Table 4. As indicated, the Trials main effect was statistically significant for all maneuvers. A significant Motion main effect during ASPT training was obtained for every maneuver except the Steep Turn. There were no significant FOV effects for any maneuver. Furthermore, none of the interaction effects reached statistical significance. As seen in Table 4, the IP ratings increased, i.e., student performance improved, with successive trials in the ASPT. For those maneuvers yielding a significant Motion effect, better performance was demonstrated by the Motion-trained group for all trials.

Table 3. **F-values for IP Overall Ratings in ASPT**

Experimental Condition	Motion (M)	FOV	Trials (T)	M x FOV	M x T	FOV x T	M x FOV x T
Takeoff	5.99*	0.14	41.03**	0.21	0.48	1.85	0.60
Steep Turn	1.34	0.52	13.24**	0.52	1.18	0.08	1.09
Slow Flight	7.66**	2.80	20.23**	0.00	0.86	1.97	0.55
Straight-In	5.87*	0.00	35.25**	1.42	0.29	0.94	0.72

*p < .05.
**p < .01.

Table 4. **Mean IP Overall Ratings**

Maneuver	ASPT Trials 1	2	3	4	T-37 Evaluation 1
Takeoff					
Motion	2.06	4.94	5.50	6.00	3.88
No-Motion	1.31	3.50	4.94	5.06	2.56
Full FOV	1.69	4.69	4.81	5.75	3.00
Limited FOV	1.69	3.75	5.62	5.31	3.44
Total	1.69	4.21	5.22	5.53	3.22
Steep Turn					
Motion	2.69	5.19	5.38	5.25	3.06
No-Motion	2.56	3.69	4.81	5.44	1.94
Full FOV	2.56	4.25	5.00	5.06	2.50
Limited FOV	2.69	4.62	5.19	5.62	2.53
Total	2.62	4.44	5.09	5.34	2.52
Slow Flight					
Motion	3.25	5.88	6.50	6.50	3.31
No-Motion	2.63	3.94	5.00	5.50	2.25
Full FOV	3.12	5.94	5.94	6.12	2.94
Limited FOV	2.75	3.88	5.56	5.88	2.67
Total	2.94	4.91	5.75	6.00	2.81
Straight-In					
Motion	1.88	3.00	5.62	5.88	2.44
No-Motion	1.38	1.94	4.50	4.62	1.94
Full FOV	1.56	2.88	5.06	4.94	2.00
Limited FOV	1.69	2.06	5.06	5.56	2.43
Total	1.62	2.47	5.06	5.25	2.20

APMS Deviation Scores. Of the two sets of APMS scores, deviations from desired state values are considered to be of greater importance since they provide some indication of proficiency. Results of the ANOVAs on *ln* RMS deviation scores for each of the maneuvers are presented in Table 5, with descriptive statistics in Table 6.

For the Takeoff, only Heading Deviation produced a significant Trials effect. Descriptive statistics presented in Table 6 show decreases in Heading Deviation scores with successive trials. Two additional

Table 5. **F-values for APM *ln* RMS Deviation Scores**

Measure	Motion (M)	FOV	Trials (T)	M x FOV	M x T	FOV x T	M x FOV x T
			Takeoff				
Heading	3.62*	0.04	27.89***	1.42	0.38	1.30	0.09
Attitude	1.06	1.07	1.75	0.06	0.60	1.86	3.36**
Climbpath	0.33	0.11	0.52	0.05	0.16	1.27	0.61
			Steep Turn				
Airspeed	0.03	0.33	5.50***	0.34	1.97	0.20	1.43
Altitude	3.07*	1.61	4.69***	1.03	1.13	0.76	0.56
Bank	0.92	0.83	3.50**	0.12	0.51	0.82	0.67
			Slow Flight				
Altitude	1.36	0.50	8.29***	0.48	0.54	1.11	0.88
Airspeed	0.93	1.11	3.50**	2.36	0.82	1.05	1.60
Heading	1.22	0.74	8.56***	0.60	0.32	1.24	0.56
			Straight-In (Before Glidepath)				
Altitude	5.01**	1.56	7.20***	0.02	1.00	0.13	0.73
Centerline	1.60	0.24	1.16	0.00	1.35	1.27	1.27
			Straight-In (On Glidepath)				
Glidepath	7.78***	0.15	6.87***	1.34	0.97	0.81	1.32
Centerline	3.90*	1.17	3.27**	1.98	1.07	0.58	0.57
Airspeed	1.53	1.13	11.56***	0.20	0.91	0.02	2.45*

*$p < .10$.
**$p < .05$.
***$p < .01$.

Table 6. **Mean *ln* RMS Deviation Scores**

Measure	Motion		FOV		Trials			
	On	Off	Full	Limited	1	2	3	4
				Takeoff				
Heading	0.42	0.57	0.51	0.49	0.91	0.56	0.33	0.19
Attitude	0.78	0.88	0.88	0.79	0.86	0.93	0.82	0.70
Climbpath	5.50	5.58	5.52	5.56	5.59	5.55	5.56	5.45
				Steep Turn				
Airspeed	1.52	1.54	1.56	1.50	1.81	1.44	1.41	1.46
Altitude	4.35	4.54	4.37	4.51	4.74	4.33	4.36	4.34
Bank	1.42	1.32	1.42	1.32	1.54	1.35	1.29	1.30
				Slow Flight				
Altitude	4.16	4.37	4.20	4.33	4.77	4.31	1.07	3.90
Airspeed	0.90	1.01	0.89	1.01	0.96	1.13	0.93	0.77
Heading	1.54	1.76	1.56	1.73	2.14	1.39	1.57	1.48
				Straight-In (Before Glidepath)				
Altitude	3.71	4.00	3.78	3.94	4.18	3.93	3.71	3.61
Centerline	4.66	4.78	4.70	4.74	4.84	4.74	4.70	4.59
				Straight-In (On Glidepath)				
Glidepath	3.47	3.88	3.71	3.65	4.06	3.84	3.51	3.29
Centerline	3.29	3.57	3.51	3.35	3.71	3.36	3.34	3.31
Airspeed	0.93	1.09	0.95	1.08	1.45	1.10	0.76	0.73

F-ratios were also significant—a Motion effect for Heading Deviation ($p < .10$) and a three-way interaction for Attitude Deviation ($p < .05$). For Heading Deviation, the Motion group had smaller scores than the No Motion group at each measured trial. For Pitch Attitude Deviation, there occurred a significant decrease in errors for only one condition, Motion/Limited FOV. No other FOV effects were obtained.

For the Steep Turn, a significant Trials effect was obtained for each parameter. As seen in Table 6, there was a general trend for both groups to improve in performance with increasing trials. Altitude Deviation was also significant ($p < .10$) for the Motion factor. The Motion group performed better than the No Motion group at each measured trial. No FOV effects were obtained.

For Slow Flight, significant differences were obtained for the Trials effect only. As shown in Table 5, these differences were obtained for all parameters. Descriptive data indicate generally improved performance across the four trials. No Motion or FOV effects were obtained.

The Straight-in Landing was scored in two separate phases. During the portion before intersection of the glidepath, Altitude Deviation produced statistically significant differences for both Motion ($p < .05$) and Trials ($p < .01$). As seen in Table 6, the Motion group performed better than the No Motion group at each measured trial. Also, both groups improved with successive trials. The second phase of the Straight-in Landing was scored while "on glideslope." As shown in Table 5, a significant Trials effect was obtained for each parameter, with the descriptive data indicating improved performance over the trials. For the Motion factor, significant differences were obtained for Glidepath Deviation ($p < .01$) and Centerline Deviation ($p < .10$), with the Motion-trained group demonstrating better performance in each case. A significant third-order interaction was also obtained for Airspeed Deviations ($p < .10$). However, no apparently meaningful trends emerged. No other FOV effects were obtained.

APMS Control Input Scores. ANOVAs for control input scores (*ln* RMS movement scores) for each of the maneuvers are presented in Table 7. Descriptive statistics are found in Table 8. For the Takeoff, a significant Trials effect was obtained for each parameter. Descriptive data in Table 8 indicate that the RMS scores decreased as the subjects had more practice on the maneuver. A significant ($p < .10$) Trials by FOV interaction for Elevator movement was also obtained. A rapid decrease in movement between the first and second trial occurred for the Limited FOV groups, while the decrease for the Full FOV groups was more gradual.

For the Steep Turn, the Trials main effect was statistically significant for each of the control input parameters. The descriptive data indicate increased Throttle movement over the four trials with a decrease in other control movements, especially between the first and second measured trials.

Data were recorded for two separate phases of the Slow Flight maneuver. During the portion of the maneuver in which the subjects were configuring the ASPT, a significant difference between the Motion groups was obtained for Elevator movement. As seen in Table 8, the Motion groups produced higher Elevator movement scores than the No Motion groups. For the Trials effect, significant univariate ANOVAs were obtained for Elevator and Throttle movement. During that portion of slow flight following configuration, significant FOV differences were obtained for Elevator movement, with greater scores produced in the limited FOV condition. The significant Trials effect for Aileron control was produced by decreased movement, especially between the first and second measured trials.

The Straight-In Landing performance was also scored in two phases: before intersection of the glidepath and while "on glidepath." Before intersection of the glidepath, the Trials main effect was statistically significant for Aileron and Elevator control inputs while the Motion effect was significant for Elevator control. Descriptive data indicate that both the Motion and No Motion groups had smaller *ln* RMS Movement Scores with successive trials. Also, the Motion groups had higher scores than the No-Motion groups at each trial. In the ANOVAs "on glidepath," the Trials main effect was again significant for Aileron and Elevator control inputs. However, for the Elevator movements, both Motion and FOV were significant. Descriptive data revealed that the Motion groups produced higher scores than the No Motion groups and that all groups had lower scores with successive trials. Furthermore, the full-FOV subjects had consistently lower Elevator control scores than those trained with the limited FOV.

Table 7. **F-values for APMS *ln* RMS Movement Data**

Measure	Motion (M)	FOV	Trials (T)	M x FOV	M x T	FOV x T	M x FOV x T
			Takeoff				
Aileron	0.02	1.20	2.72**	0.00	0.79	1.29	0.55
Elevator	0.80	1.06	23.23***	0.25	0.12	2.60*	0.42
			Steep Turn				
Aileron	0.04	1.46	3.31**	0.12	0.16	0.84	0.38
Elevator	1.09	0.39	13.40***	0.42	0.79	0.21	0.66
Throttle	0.78	0.00	3.96**	1.99	0.18	2.06	0.04
			Slow Flight (While Configuring)				
Aileron	0.00	1.44	1.88	2.29	0.55	1.09	0.64
Elevator	7.00**	2.22	2.13*	0.06	0.15	0.56	1.10
Throttle	0.01	1.36	2.12*	0.16	0.44	1.69	0.12
			Slow Flight (After Configuring)				
Aileron	0.03	0.58	3.34**	0.07	0.24	1.13	0.38
Elevator	0.97	3.08*	1.97	0.00	0.63	1.62	0.31
			Straight-In (Before Glidepath)				
Aileron	0.02	0.08	3.61**	0.02	0.68	1.71	0.74
Elevator	9.13***	2.77	9.42***	0.07	0.56	1.45	0.57
Throttle	0.04	0.32	1.11	0.01	1.22	1.85	0.86
			Straight-In (On Glidepath)				
Aileron	0.14	0.00	3.46**	0.03	0.60	1.74	0.62
Elevator	6.96**	3.74*	17.21***	0.24	0.04	0.72	0.99
Throttle	0.00	0.12	1.30	1.99	0.81	1.50	0.99

*$p < .10$.
**$p < .05$.
***$p < .01$.

Table 8. **Mean *ln* RMS Movement Scores**

	Motion		FOV		Trials			
Measure	On	Off	Full	Limited	1	2	3	4
				Takeoff				
Aileron	2.76	2.74	2.82	2.67	3.02	2.63	2.79	2.56
Elevator	1.04	0.96	.96	1.04	1.40	0.97	0.90	0.73
				Steep Turn				
Aileron	2.58	2.56	2.64	2.50	2.84	2.41	2.62	2.40
Elevator	0.61	0.54	0.56	0.60	0.77	0.54	0.48	0.51
Throttle	1.30	1.37	1.33	1.33	1.16	1.33	1.36	1.48
				Slow Flight (During Configuration)				
Aileron	2.71	2.71	2.79	2.63	2.91	2.60	2.76	2.58
Elevator	0.63	0.41	0.45	0.58	0.58	0.52	0.50	0.46
Throttle	1.34	1.35	1.26	1.43	1.24	1.45	1.44	1.24
				Slow Flight (After Configuration)				
Aileron	2.98	2.96	3.02	2.93	3.22	2.84	3.00	2.82
Elevator	0.46	0.35	0.31	0.51	0.51	0.45	0.32	0.36
				Straight-In (Before Glidepath)				
Aileron	2.43	2.41	2.43	2.40	2.65	2.32	2.45	2.26
Elevator	0.38	0.12	0.18	0.33	0.38	0.28	0.19	0.16
Throttle	1.33	1.32	1.30	1.34	1.25	1.37	1.35	1.32
				Straight-In (On Glidepath)				
Aileron	2.33	2.29	2.32	2.31	2.52	2.22	2.35	2.16
Elevator	0.41	0.17	.20	.28	0.46	0.30	0.24	0.16
Throttle	1.37	1.36	1.35	1.38	1.38	1.42	1.37	1.30

T-37 Evaluation Data

Of primary interest was the effect which Motion and FOV in the ASPT would have on performance in the T-37. For each maneuver, a series of two-factor, completely randomized factorial ANOVAs were computed using information from the special data cards. The results of these ANOVAs are summarized in Table 9, with descriptive statistics presented in Table 10.

Table 9. **F-values for T-37 Evaluation Scores**

Measure	Motion (M)	FOV	M x FOV
Takeoff			
Pitch Range	.45	3.42*	3.42*
Rotation Speed	5.83*	.34	.53
Ground Deviation	.20	.55	1.08
Liftoff Deviation	4.98*	.03	.10
IP Rating	2.80	.31	.06
Steep Turn			
Altitude Range	.48	.57	.16
Bank Range	.03	1.56	.04
Airspeed Range	.79	.79	.12
IP Rating	2.38	.00	1.61
Slow Flight			
Altitude Range	.64	.22	.15
Airspeed Range	.00	.00	.00
Heading Range	1.38	.42	1.63
IP Rating	1.85	.15	.02
Straight-In (Before Glidepath)			
Altitude Range	1.70	.19	1.38
Airspeed Range	.00	2.66	2.66
Centerline Deviation[a]	.00	.28	-
Straight-In (On Glidepath)			
Altitude Deviation	.03	.02	.02
Airspeed Range	.16	.06	2.03
Centerline Deviation[a]	2.25	.05	-
IP Rating	.55	.46	.22

[a]Chi-squares.
* $p < .05$.

Table 10. **Mean T-37 Evaluation Data**

Measure	Motion On	Motion Off	FOV Full	FOV Limited	Motion-On Full	Motion-On Limited	Motion-Off Full	Motion-Off Limited
Takeoff								
Pitch Range	4.04	4.47	4.84	3.67	5.21	2.87	4.47	4.47
Rotation Speed	64.63	68.25	66.88	66.00	64.50	64.75	69.25	67.25
Ground Deviation	25.13	28.61	29.77	23.97	32.09	18.17	27.45	29.77
Liftoff Deviation	30.93	57.41	43.92	45.23	31.81	30.15	54.51	60.31
IP Rating	3.88	2.56	3.00	3.44	3.75	4.00	2.25	2.88
Steep Turn								
Altitude Range	266.77	308.86	308.54	264.30	277.21	256.33	339.87	273.42
Bank Range	10.47	10.78	9.33	12.00	8.92	12.03	9.74	11.97
Airspeed Range	11.82	13.92	11.82	13.92	10.33	13.30	13.30	14.62
IP Rating	3.06	1.93	2.50	2.53	3.50	2.63	1.50	2.43
Slow Flight								
Altitude Range	213.28	257.50	247.26	221.25	215.63	210.94	278.91	233.04
Airspeed Range	3.09	3.06	3.07	3.04	3.06	3.11	3.09	3.02
Heading Range	9.45	13.38	10.55	12.21	5.41	13.49	15.70	10.74
IP Rating	3.32	2.27	2.94	2.67	3.63	3.00	2.25	2.29
Straight-In (Before Glidepath)								
Altitude Range	146.52	175.28	154.10	165.10	129.10	163.93	182.67	166.67
Airspeed Range	8.39	8.67	9.67	7.28	8.39	8.39	11.13	5.80
Centerline Deviation	62.50	61.54	66.67	57.14	–	–	–	–
Straight-In (On Glidepath)								
Altitude Deviation	64.58	61.91	62.15	64.68	62.50	66.67	61.81	62.04
Airspeed Range	7.14	8.10	7.73	7.43	6.05	8.23	9.41	6.36
Centerline Deviation	87.50	64.29	7.500	78.57	–	–	–	–
IP Rating	2.44	1.93	2.00	2.43	2.38	2.50	1.63	2.33

For the Steep Turn, Slow Flight, and the Straight-In Landing, no significant effects on the T-37 evaluation sortie were found for any of the measures. For the Takeoff, significant Motion effects were obtained for Rotation Speed and Centerline Deviation following Lift-off. Rotation Speed was found to be significantly lower for the Motion groups. Likewise, Centerline Deviations following Lift-off were smaller for the Motion-trained groups. Despite these effects, the overall IP rating was not significant, although the trend was in favor of the Motion-trained groups. Significant FOV and Motion by FOV effects were also obtained for Pitch Range. Descriptive data revealed a smaller Pitch Range for the Limited FOV groups under conditions of motion cueing. No FOV effects were obtained for the No Motion condition.

IV. DISCUSSION

For data collected in the simulator, two questions were of interest. The first was whether learning occurred during simulator training. The second was whether any differential skill acquisition effects were apparent as a result of Motion, FOV, or their interaction. With respect to the first question, the data are clear Student performance improved significantly across the four trials as measured by IP ratings, as well as scores from the APMS. The IP ratings significantly increased, while error scores from the APMS decreased.

To answer the second question and conclude that Motion, FOV, or their interaction affects skill acquisition in the simulator, it is necessary to demonstrate learning curve differences among the groups. In other words, significant interactions effects with the Trials factor must occur. For the IP ratings, no such interactions occurred. Two significant third-order (Motion x FOV x Trials) interactions were obtained using the APMS error scores. For Pitch Attitude error during Takeoff, only the Motion/Limited FOV group showed significant improvement during simulator training. None of the remaining groups improved their performance. For Airspeed error on the Straight-In, no meaningful trends were observed. Thus, there is little evidence that Motion, FOV, or their interaction significantly affected skill acquisition in the simulator.

Significant performance differences did occur, however, among the groups during simulator training for the Motion factor. Using IP ratings, significant motion effects were obtained on three maneuvers: Takeoff, Slow Flight, and Straight-In Landing. As evidenced by the descriptive data, the Motion-trained groups received higher ratings for each measured trial on these three maneuvers and for three of the four measured trials on the Steep Turn. Likewise, five of the 14 error scores from the APMS produced significant motion effects. Consistent differences across the four trials were observed, with lower error scores being produced by the Motion groups. Since these differences were consistent across all measured trials and there occurred no significant Motion by Trials interaction, it is clear that performance, rather than learning, was impacted. Unfortunately, the underlying reason for these differences is unknown and cannot be determined from the data; however, a discussion of possible explanations seems warranted.

The most obvious explanation is that platform motion cueing produced the observed differences; however, such results are contradictory to previous study findings using the ASPT with student pilots (Martin & Waag, 1978a; 1978b), as well as with experienced pilots (Irish & Buckland, 1978; Irish, Grunzke, Gray, & Waters, 1977). Second, it is possible that there existed initial group differences which accounted for the better performance of the Motion groups, although the likelihood of such an occurrence should be small, given the sample size. Third, it is possible that there may have existed some IP bias. However, this explanation is also unlikely since differences were obtained using the objective APMS error scores. Thus, it seems that each of the potential explanations is not completely satisfactory.

As indicated earlier, control input data are not directly related to proficiency. However, they do provide information on control strategy as affected by various simulator configurations. Three measures of control activity were analyzed: RMS movement for Elevator (Y-axis), Aileron (X-axis), and Throttle. The most striking finding is the relatively large amount of control activity in the X-axis (aileron), which would confirm the excessive "roll sensitivity" reported by pilots flying the ASPT.

The most consistent finding using these control input measures was a significant Trials effect. Descriptive data indicated a decreased amount of Elevator and Aileron movement and an increased amount of Throttle movement. With respect to Motion and FOV, the only measure to yield significant effects was Elevator movement. With regard to Motion, significant effects were obtained for Slow Flight while configuring and for both phases of the Straight-In Landing. Students in the Motion-trained groups produced more Elevator Movement, a finding consistent with previous efforts using experienced pilots in the ASPT (Irish & Buckland, 1978; Irish *et al*, 1977). Significant FOV effects were obtained for Slow Flight after configuration and the glidepath portion of the Straight-In Landing. The limited FOV condition produced greater movement. Thus, it would appear that the addition of platform motion cueing and the use of a narrow FOV visual system increases the amount of elevator control activity. These effects are most pronounced whenever the simulated aircraft's stability is decreased during configuration changes necessary for landing and during the final approach itself.

For transfer-of-training data collected in the aircraft, neither Motion, FOV, nor their interaction during simulator training differentially affected performance as measured by IP ratings. There was a trend toward better performance by the Motion-trained groups. Of the 16 parameters recorded by the IPs on the special data cards, two produced significant Motion effects. Both occurred during the Takeoff-Rotation Speed and Centerline Deviation Range following Liftoff. A significant Motion by FOV interaction for Pitch Range, with lower scores under the Limited FOV condition occurred whenever the platform motion system was operative. Thus, of the 58 statistical tests computed on the aircraft evaluation data, only three produced significant effects. The extent to which these represent real effects is unknown, since the probability of significant differences given the number of tests is quite high.

It is possible, however, to compare these aircraft differences with data collected during ASPT training. In the event the results are consistent, greater confidence could be placed on the conclusion that the effects are real. For Rotation Speed during Takeoff, the simulator data revealed no significant effects due to Motion. By the fourth trial, average Rotation-Speed across the four groups varied by less than one knot. For Centerline Deviation Range following Lift-off, a significant effect due to Motion occurred, although RMS heading error showed no differences. For Pitch Attitude Range, a third-order interaction was obtained in which only the Motion/Limited FOV group showed significant improvement. Similar findings were obtained for RMS Pitch Attitude error. Thus, of the two measures producing significant Motion effects in the aircraft, only one showed similar effects in the simulator. Likewise, the one significant Motion by FOV interaction in the aircraft was also significant in the simulator. However, it is curious why three of the four groups showed no improvement during simulator training on this measure.

A major criterion for accepting the findings of any differential transfer is the demonstration that transfer of learning did in fact occur. The present study did not include a control group, so this question cannot be answered unequivocally. Current Air Training Command requirements prohibit the students from flying the maneuvers in the T-37 before they are demonstrated by the IP. The additional training in the ASPT enabled a waiver on that requirement for the experimental groups. However, it was not possible to evaluate the performance of a control group in the aircraft.

Despite the lack of control group data, there are good reasons to "assume" that transfer of learning did occur. First, significant improvements in simulator performance were obtained. On the last simulator sortie, average performance levels were in the "Good" range for all maneuvers. Furthermore, there is evidence that student performance levels had stabilized by the last sortie. Statistical tests revealed no significant improvements in performance between the third and fourth sorties as measured by IP ratings. In addition to the demonstration of learning in the simulator, additional support for assuming positive transfer can be derived from previous research results. With few exceptions, positive transfer of learning has been demonstrated for these transition tasks for every class of aircraft (trainer, fighter, transport). Furthermore, there is specific evidence that such training in the ASPT transfers to the T-37 aircraft (Martin & Waag, 1978a; Woodruff et al., 1976). Therefore it seems likely that positive transfer did occur. Furthermore, a look at the data recorded in the aircraft revealed that most parameters are within the Good to Excellent category as defined by the criteria on the special data cards.

Aside from the lack of control group data, there occurred other problems which are characteristic of most transfer-of-training evaluations. These have been described in detail by Martin and Waag (1978a, 1978b) so that further discussion seems unwarranted. The one aspect of the study where comment does seem appropriate is in the area of task selection; that is, whether the tasks selected for training were appropriate to the questions being asked. It can be argued that none of the tasks require peripheral visual cues so that the FOV question is not properly addressed. With respect to motion, the distinction between maneuver cueing and disturbance cueing has recently been investigated (Caro, 1977). Accordingly, there are data to suggest that platform motion cueing becomes a critical variable only for tasks having a large disturbance component. Since the tasks selected for the present study provide little disturbance cueing information (e.g., slow flight and the change of configuration during the straight-in landing), it may be argued that the motion question is not properly addressed.

It is agreed that such arguments have merit when one attempts to answer the general question of motion and visual cueing requirements. However, as stated at the outset, the intent of the present series of studies was to address a very specific and limited question––the effectiveness of platform motion cueing for naive UPT students transitioning into the T-37 aircraft. For this reason, tasks were selected which are normally taught in the T-37 training program. Very few tasks in the T-37 training syllabus provide significant disturbance cues. Only stalls are currently being trained in the new Air Training Command Instrument Flight Simulator. For these maneuvers, it has been demonstrated that requiring the IP to manually shake the stick was as effective as platform motion in providing the stall onset cues (Martin & Waag, 1978a). For these reasons, the tasks selected seem adequate to address the motion issue posed at the outset. With respect to field-of-view, the question posed was whether the addition of platform motion cueing enhanced the effectiveness of training with a limited FOV visual environment. The use of tasks normally trained using a narrow FOV system seemed most appropriate to answer this question.

V. CONCLUSIONS

The data from the present study warrant the following conclusions.

1. No firm evidence of differential transfer effects resulting from platform motion cueing, size of the visual FOV, or their interaction was obtained; as such, these data provide support for previous findings that platform motion cueing does not significantly enhance the transfer of learning for basic contact tasks in the T-37 aircraft.

2. It would seem that the impact of peripheral visual cues for initial acquisition is not critical; furthermore, no convincing evidence was found indicating increased transfer using platform motion in conjunction with a narrow FOV visual scene.

3. In addition to the lack of differential transfer to the aircraft, there also occurred no differential effects upon learning in the simulator.

4. Performance differences in the simulator did occur although the underlying reason is unclear; for certain measures, the motion group performed consistently better on all measured trials, including the first.

5. It seems reasonable to conclude that, taken as a whole, no substantial or practical differences in training effectiveness resulted from manipulations of platform motion cueing and the FOV of the visual scene.

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APPENDIX A: PRE-FLIGHT BRIEFING

Welcome to the Air Force Human Resources Laboratory (AFHRL). This is the simulator pre-flight briefing for the HRL VISMO study. VISMO is an acronym for Visual in Motion Configuration Changes. (Kinda catchy isn't it?) In this phase of the Study, you will be receiving four simulator flights and one flight in the T-37, during which time you will learn normal takeoffs, straight-ins and landings, steep turns, and slow flight. During the early part of each sortie, you will first review a demonstration of each one of the four maneuvers. After that, you will have several practice repetitions. Following the practice session, there will be a data-collection period where we will assess your ability to perform the maneuver. Do your best at all times, because this will not only make each maneuver more meaningful for you, but it will also provide us with the most valid data for our review.

Let's first discuss the various techniques for each one of the four maneuvers, and the first one we will cover is the normal takeoff. The first thing I would like you to note is where the horizon falls in the windscreen. You notice here that it cuts halfway through the windscreen. From your seat position, you should be able to look right through the center of the windscreen and see half sky and half ground. Prior to initiating the takeoff, you will pump up the brakes and perform the normal lineup check.

After checking the instruments good, you will engage the nosewheel steering on the front of the stick grip–a little red button right on the front. Then, you will release the brakes. Remember to release the brakes evenly and initiate the takeoff roll. You use the nosewheel steering and the rudder pedals to keep the aircraft on the center line of the runway. At approximately 65 knots, you release the nosewheel steering and raise the nose to establish the takeoff attitude. You simply do this by pulling back on the stick a slight amount. Note the new position of the horizon in the windscreen here. This picture corresponds to a 5° pitch attitude–the same attitude you would see if you had 5° on the attitude indicator. By maintaining this attitude, the aircraft should lift off at approximately 90 knots. As the aircraft leaves the runway, you will maintain the wings level by controlling the ailerons. There is a natural tendency to rock the wings. Let's try to avoid that by controlling it with the ailerons. At 100 knots and the engine instruments checked good, retract the gear by raising the handle with your left hand. At 110 knots, retract the flaps by pushing the flap lever all the way to the top. Now, raising the flaps will cause a slight loss of lift for which you will compensate by pulling back on the stick and trimming off the pressure. As the airspeed increases, trim off all the stick forces that will build up as a result of the increased airspeed. Once the gear and flaps have been retracted, maintain the 500 to 1000 feet per minute on the vertical velocity until you're ready to turn on the traffic. The takeoff is a critical phase of flight requiring the utmost attention of you, the pilot, at all times. You must be constantly alert for the sudden loss of thrust due to engine failure or some other catastrophe, to make sure that you are flying as safely as possible at all times.

The next maneuver will be the steep turn. This maneuver should be entered from a fully-trimmed condition in straight and level flight at a 160 knots. And, of course, the simulator will be given to you in that condition all the time. Remember that during the 60° bank turn that you will being flying, approximately 2g is required to maintain a level turn–that is to maintain your altitude. Although the g forces in the airplane are much more apparent than they are in the simulator, be aware that the stick force you will have to use in the simulator will be the same. Always begin the roll-in slowly, and as you pass through 30° bank, you gently begin to increase the back pressure and add the power, as required, to maintain altitude and airspeed. The back pressure required, and the back pressure that you have to put in, will cause increased drag and that's what causes the airspeed to slow down. You counterbalance the loss of airspeed by adding enough power to keep the airspeed right at 160 knots. Now, as you approach 60° of bank, continue to monitor the airspeed while increasing the back pressure. It's an ever smooth increasing back pressure all the way to the max bank angle. Use the horizon line depicted here, as well as the attitude indicator to maintain your pitch and your bank references. When rolling out of the turn, decrease the back pressure and reduce the power to the appropriate setting that you had in straight-and-level flight. Continue to use the horizon and the attitude indicator for pitch and bank information even after you've rolled out, because you are going to roll out to straight-and-level flight. Remember to monitor the airspeed. The rollout should ultimately return the aircraft to the same conditions as at the beginning, except for the heading change that you made while you were in the turn.

The next maneuver is called slow flight. This is a little more difficult maneuver. Prior to entering this maneuver, the aircraft should be again stable, trimmed, straight-and-level flight, at 160 knots. Also, your instructor will hand you the simulator controls in this condition. To begin, lower the speed brake and reduce the power. This will begin to slow the airplane down toward the target airspeed of 75 to 80 knots. Maintain the altitude by pulling back a slight amount on the stick, as necessary, and raising the nose to compensate for the decreasing airspeed. What that means is, as the airspeed depletes, the nose will want to drop, and you will have to keep it up by pulling back on the stick slightly. When the airspeed drops below 150 knots, lower the gear. Remember to hold altitude with pitch control. When the airspeed drops below 135 knots, lower full flaps by pushing the flap lever to the full-down position. This is the final configuration change. In other words, we won't change the configuration anymore during this maneuver. By this time, the airspeed will probably be very close to the desired airspeed, that is, 75 to 80 knots. You continue to hold the nose up as necessary to maintain altitude and trim to relieve the undesired stick forces that will occur from the rapidly depleting airspeed. Prior to the airspeed actually reaching 75 to 80 knots, you are going to have to lead the power: that is, at about 82 to 83 knots or so, push the power into approximately 90 percent. This will prevent the airspeed from dropping below 75 knots and causing the airplane to stall. When you have the aircraft stabilized at straight-and-level, and at fully trimmed condition, nose high, and 75 to 80 knots, you are in slow flight: and, while you are in slow flight, you will be expected to maintain heading, altitude, and airspeed. You won't do any coordinated turns or any other maneuvers of that nature. Now, I would like you to notice the relative position of the horizon in the wind screen during the slow flight maneuver. The pitch attitude is very very high. You can see here that the horizon is resting just on top of the wind screen. The slow flight maneuver was designed to acquaint you with the characteristics of the airplane when flying at minimum controllable airspeeds. This is similar to the conditions that you might encounter after initially initiating the go-around.

Now, the next maneuver will be the straight-in approach and landing. The straight-in approach will be started at approximately 5 miles from the runway 5000 feet above the ground and at about 150 knots. The power will be set at about 70 percent–plus or minus some small amount. You will be required to make the radio calls; the appropriate calls at the 5- and the 2-mile points. Your instructor will tell you what they are, where they are, and where they should occur. To initiate the approach, make sure the airspeed initially is below 150 knots. When it is, then you lower the gear handle and make all the gear-down checks. At 135 knots or below, you will lower the flap handle to the full-down position, and also the landing lights. As the airspeed decreases, you will have to add back-pressure to maintain the desired altitude and trim off the undesired stick forces that will result. This is done in much the same manner as you did in slow flight. In other words, the airplane is slowing down, the nose is coming up, and you are trimming off the pressure. The main difference here, of course, is the fact that you're not going to slow down to 75 to 80 knots. You are going to reduce your airspeed to 100 knots. Also, the speedbrake in the straight-in approach is not used until we initiate the glidepath. Now, also, like in slow-flight, as the airspeed reaches the desired airspeed (that is, again 100 knots), you will have to add power to approximately 80 percent, in other words, leading the power. To maintain the airspeed and the altitude, always align with the centerline of the runway until you are approximately 1–1/4 miles from the runway. At this point, you are going to extend speedbrake by sliding back the slide switch on the left throttle, reduce the power slightly, and set up a glidepath. Now, as you enter the glidepath, you will begin a descent to the runway. You select the aim point and the most common technique for doing this is to lower the nose until the aim point, that, the runway threshold, is right in the middle of the windscreen. This is the same location that the horizon would be in a straight-and-level flight. Here you will notice that the runway is just about in the middle of your windscreen. You continue to fly the airplane down towards your aim point maintaining 100 knots and the centerline of the runway with your bank control. If you are on the proper glidepath, the aircraft will pass through 1700 feet indicated at 3/4 mile from the runway. Be particularly aware of all the signs that may indicate to you an engine failure, because again this, like the takeoff, is a critical phase of flight. It is very important that you are tuned to this possibility at all times. Now, as the aircraft approaches the runway touchdown zone, you will smoothly reduce the power and gently pull back on the stick, gently raising the nose to establish the landing attitude. The aircraft will touch down at approximately 75 to 80 knots (the same airspeed you use for slow-flight). You should plan the touchdown so that it occurs in the first 1000 feet of the runway. Once you are on the runway, you continue to hold the nosewheel up off the ground by keeping the stick a little bit back toward your lap until the elevator loses its control effectiveness. Now this is going to occur at about 60 to 65 knots. After lowering the nosewheel to the runway, and you simply do that by pushing the stick forward and letting the nosewheel touch (and you'll feel it), then you will retract the speedbrake. The rudder will lose its effectiveness at approximately 50 knots, so at this point, you will engage the nosewheel steering after you check the rudder pedals neutral and maintain your directional control down the centerline of the runway using the rudder pedals and the nosewheel steering. Before reaching the end of the runway, gently touch the brakes to insure proper operation. When I say gently, I mean just that. Don't push them so hard you get a gigantic lurch in the airplane. Just push them a small amount so you feel a little resistance. You see, the brakes not only are used for normal stopping, but they can be used for emergency turning if the need arises.

Well, this concludes the pre-flight briefing for Phase 1 of the AFHRL VISMO Study. I hope I haven't bored you too much. No, seriously, if you have any questions, feel free to ask your instructor pilot or any of the research investigators that are on site at the simulator area. Good luck to you, and when you come over here, I'm sure you will have a good time. Enjoy yourself!

APPENDIX B: SPECIAL DATA CARD DEVELOPMENT

An initial draft grading form was prepared for each maneuver. Although the straight-in and landing were flown as a single continuous maneuver, two grading forms were prepared. The first form included that portion of the maneuver prior to interception of the glidepath. The second form included the segment from interception of the glidepath until touchdown. These initial draft grading forms were then reviewed by several Instructor Pilots (IPs). Based on the comments which were made, the initial grade sheets were revised. The next phase of score sheet development involved their actual use in the evaluation of recorded flight performance. Two flights were recorded for each maneuver. One of them was representative of "fair" performance; the other was representative of "good" performance. Each IP evaluated all eight recorded flights with the initial score sheets. The next day, the IPs were shown how each of them had evaluated the respective recorded flights. The IPs also presented and discussed ways in which the score sheets could be improved.

Based on comments by the IPs, the score sheets were again revised. These score sheets were used to evaluate a second set of eight recorded flight performances. The score sheets were again revised on the basis of in-depth comments from the IPs. That revision of the score sheets was used to evaluate the second set of recorded flight performance one more time. After the in-depth discussion with the IPs, the score sheets were revised for the last time. These final score sheets are presented in Figures B1 to B4.

The validity of the score sheets was assessed in conjunction with the data collection phase of the study. The final score sheets were reproduced on 5½ x 10½ inch (13.97 x 26.67 cm) cards. The score sheets were validated by correlating the corresponding scores between the IP and Automated Performance Measurement System (APMS) evaluations of both specific parameters and overall evaluations. Each IP evaluated eight students for four trials on each of the four maneuvers. Simultaneous evaluations were accomplished by the APMS.

The range of the correlations between the IP and APMS evaluations of the flight parameters in the ASPT (Table B1) was .168 to .960 with a median of .763. The lowest correlation was significant at $p < .055$; three of the correlations were significant at $p < .001$; and the remaining 25 correlations were all significant at $p < .0001$. The differences in degrees of freedom were due to occasional system failures which precluded the completion of some measured trials.

For the takeoff, the minimum pitch correlation ($r = .168$) was quite low. This possibly was due to the fact that the IPs initiated scoring of that parameter sooner than the APMS. The IPs started scoring pitch as soon as the students attempted to establish a takeoff attitude: desired rotation speed was 65 KIAS. In contrast, the APMS did not initiate scoring that parameter until airspeed reached a minimum of 75 KIAS. The novice student tended to be erratic as they established a takeoff attitude. Some of them would have a few moments with relatively low pitch angle while the IPs were evaluating their performances, but before the APMS initiated the scoring of that parameter. Perhaps it was the erratic pitch control immediately after takeoff which caused the low correlation for minimum pitch. Nonetheless, the range of takeoff correlations was .168 to .763 and the median was .551.

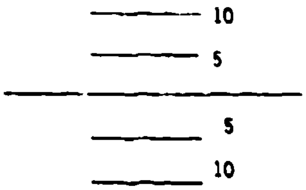
All but one of the parameters in the steep turn had correlations above .60; the range was .481 to .946 and the median was .878. Every parameter was statistically significant at $p < .0001$. Although the median slow flight correlation was slightly less (.818), the correlation for every parameter was greater than .60; the range was .602 to .925. Once again, every parameter reached statistical significance at $p < .0001$. For the straight-in and landing, half of the correlations were above .60. The range of correlations was .308 to .960; the median was .701. Three were statistically significant at $p < .001$, while the remaining were at $p < .0001$.

The results of the validation effort clearly indicate the ability of IPs to accurately record both the maximum and the minimum values of multiple parameters throughout the performance of these maneuvers.

TAKEOFF

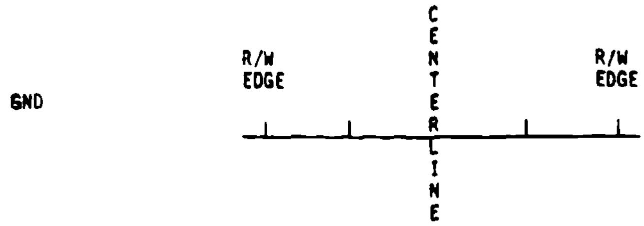
STUDENT ____________________ INSTRUCTOR ____________________

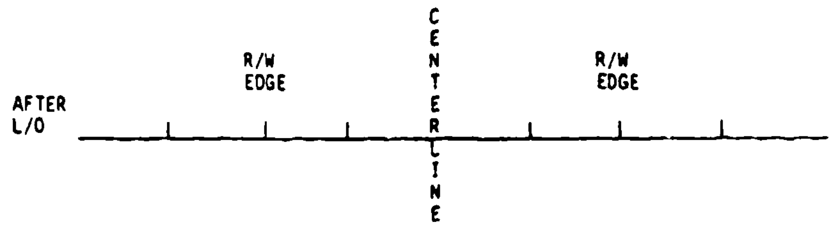
MISSION ____________________ DATE ____________ WINDS __________



PITCH ATTITUDE

ROTATION SPEED __________





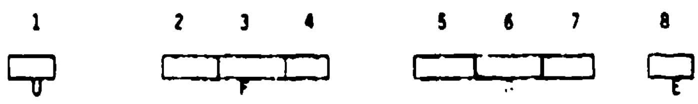
DIRECTIONAL CONTROL

CRITERIA

PITCH RANGE			ROTATION SPEED		
F	G	E	F	G	E
2°-8°	2°-6°	4°-6°	55k-60k 76k-80k	70k-75k	60k-70k
GND CENTERLINE DEV			**AFTER L/O CENTERLINE DEV**		
F	G	E	F	G	E
±35	±20	±10	±150'	±75'	±35'

In arriving at an overall rating, IP's should consider in addition to those items above, timeliness of corrections, smoothness, power control, and proper configuration.

OVERALL RATING



Form AFHRL 123 Apr 77 ONE TIME EXPIRES: SEP 77

Figure B1. Takeoff score sheet.

60 DEGREE STEEP TURN

STUDENT ______________________ INSTRUCTOR ______________________

MISSION ______________________ DATE ______________ WINDS ________

ALTITUDE DEVIATION

300'
200'
100'
0'
-100'
-200'
300'

BANK ANGLE

75 70 65 60 55 50 45

AIRSPEED DEVIATION

145K 150K 155K 160K 165K 170K 175K

CRITERIA

ALTITUDE			BANK ANGLE		
F	G	E	F	G	E
±250'	±150	±100'	±12	±10	±5

AIRSPEED		
F	G	E
160k ±12k	160k ±8k	160k ±5k

In arriving at an overall rat'ng, IP's should consider in addition to those items above, timeliness of corrections, smoothness, power control and proper configuration.

OVERALL RATING

1	2 3 4	5 6 7	8
U	F	G	E

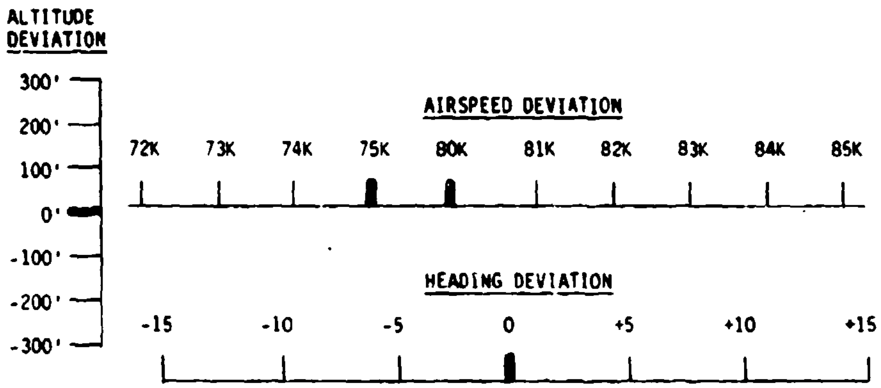
Form AFHRL 124 Apr 77 ONE TIME EXPIRES: SEP 77

Figure B2. **60-Degree steep turn score sheet.**

SLOW FLIGHT

STUDENT ______________________ INSTRUCTOR ______________________

MISSION ______________________ DATE ______________ WINDS __________



CRITERIA

ALTITUDE			AIRSPEED		
F	G	E	F	G	E
±200'	±150'	±100'	72k	74k	75k
			84k	82k	80k

HEADING		
F	G	E
±14	±10	±5

In arriving at an overall rating, IP's should consider in addition to those items above, timeliness of corrections, smoothness, power control, and proper configuration.

OVERALL RATING

1	2	3	4	5	6	7	8
☐	☐	☐	☐	☐	☐	☐	☐
U	F			G			E

Form AFHRL 125 Apr 77 ONE TIME EXPIRES: SEP 77

Figure B3. **Slow-flight score sheet.**

STRAIGHT-IN APPROACH & LANDING

STUDENT: ______________________ INSTRUCTOR: ____________________

MISSION: ______________________ DATE: __________ WINDS: ________

STRAIGHT-IN AIRSPEED (BEFORE G/P)

95K 100K 105K 110K 115K

STRAIGHT-IN ALTITUDE DEVIATION

2200'
2100'
2000'
1900'
1800'
1700'
1600'

CENTERLINE DEVIATION

WELL OFF	JUST OFF	ON

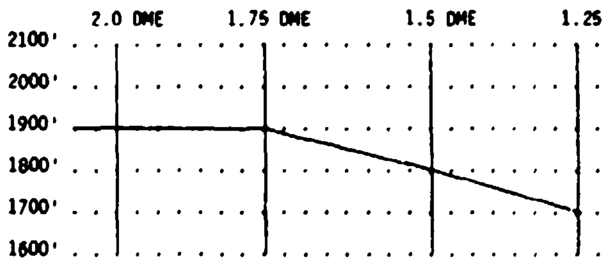
CRITERIA FOR STRAIGHT-IN

	AIRSPEED	ALTITUDE	CENTERLINE DEV
STD:	100K	1900'	ON CENTER
LIMIT:	F -2 +10	F $\pm$200'	F WELL OFF
	G -1 +10	G $\pm$150'	G JUST OFF
	E -0 +5	E $\pm$100'	E ON

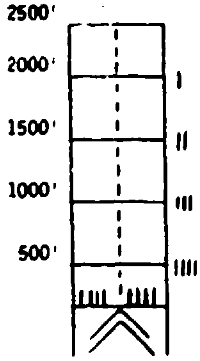
GLIDE PATH AIRSPEED

95K 100K 105K 110K 115K

GLIDEPATH ALTITUDES



TOUCHDOWN POINT



CRITERIA FOR GLIDEPATH

	AIRSPEED	ALTITUDE	TOUCHDOWN POINT
STD:	100K	ON	500-1000'
LIMIT:	F -2 +10	F $\pm$100'	F 1500-2000'
	G -1 +10	G $\pm$75'	G 0-500' 1000-1500'
	E -0 +5	E $\pm$50'	E 500-1000'

FLARE

SAFE	UNSAFE

CENTERLINE DEVIATION

WELL OFF	JUST OFF	ON

In arriving at an overall rating, IP's should consider in addition to those items above, timeliness of corrections, smoothness, power control and proper configuration.

OVERALL RATING

1	2 3 4	5 6 7	8
U	F	G	E

Form AFHRL 126 Apr 77 ONE TIME EXPIRES: SEP 77

Figure B4. **Straight-in and landing score sheet.**

Table B1. **Correlations Between IP and APM Evaluations**

Variables	r	df(n-2)	t
Takeoff			
Maximum Pitch	.763	126	13.237***
Minimum Pitch	.168	126	1.908*
Ground (Left Edge)	.456	126	5.749***
Ground (Right Edge)	.551	126	7.404***
Liftoff (Left Edge)	.620	126	8.867***
Liftoff (Right Edge)	.672	126	10.147***
Overall Score	.430	126	5.341***
Steep Turn			
Maximum Altitude	.758	125	13.026***
Minimum Altitude	.905	125	23.901***
Maximum Bank	.826	125	16.477***
Minimum Bank	.878	125	20.548***
Maximum Speed	.905	125	23.887***
Minimum Speed	.946	125	32.880***
Overall Score	.481	125	6.163***
Slow Flight			
Maximum Altitude	.912	126	24.899***
Minimum Altitude	.818	126	15.931***
Maximum Speed	.706	126	11.175***
Minimum Speed	.831	126	16.763***
Maximum Heading	.925	126	27.288***
Minimum Heading	.735	126	12.175***
Overall Score	.602	126	8.460***
Straight-In and Landing			
Maximum Altitude[a]	.960	125	38.207***
Minimum Altitude[a]	.358	125	4.305**
Maximum Speed[a]	.308	126	3.629**
Minimum Speed[a]	.329	126	3.907**
Maximum Speed[b]	.825	120	16.388***
Minimum Speed[b]	.869	120	19.715***
Touchdown Point	.860	126	18.893***
Overall Score	.576	126	7.914***

[a]prior to intersection of glidepath.

[b]on glidepath.

* $p < .055$.

** $p < .001$.

*** $p < .0001$.

APPENDIX C: DEFINITION OF PERFORMANCE MEASURES

The measures of performance used in the data analysis for each task are presented. Included are scores from the ASPT Automated Performance Measurement System as well as derived scores from the Special Data Cards described in Appendix B.

I. ASPT APMS Scores:

All scores represent RMS deviations about the desired value. For each measure, the desired value and the rules for beginning and ending the scoring are presented.

A. Takeoff

1. Heading Deviation. Desired heading 301°. Measured from brake release until 1900 feet.

2. Pitch Attitude. Desired value is 6.1°, a criterion derived by having experienced IPs fly the maneuver. Measured from 75 knots until flaps are retracted.

3. Climbout Altitude. Desired value is a function of airspeed. Desired altitude = 1900 – (196 – Airspeed)^{10}. Measured from 1500 feet (100 feet AGL) and terminates at 1900 feet.

B. Steep Turn

1. Airspeed. Desired value is 160 knots. Measured continuously.

2. Altitude. Desired value is 15,000 feet. Measured continuously.

3. Bank. Desired value is 60°. Measurement begins 6 seconds after bank greater than 40° and terminates upon computer command to "roll out".

C. Slow Flight

1. Altitude. Desired value is 15,000 feet. Measurement begins 6 seconds after indicated airspeed is less than 85 knots and continues for 30 seconds.

2. Airspeed. Desired value is 77.5 knots. Same start/stop logic as Altitude.

3. Heading. Desired value is 180°. Same start/stop logic as Altitude.

D. Straight-In Landing

1. Final Approach Altitude. Desired value 1900 feet. Measurement begins 15 seconds after Unfreeze. Continues until glidepath intersection at 1.25 NM.

2. Centerline. Desired value is zero. Same start/stop logic as Final Approach Altitude.

3. Glidepath. Desired value is zero. Begins at 1.25 NM and terminates at 1000 feet from end of runway.

4. Centerline. Desires value is zero. Same start/stop logic as Glidepath.

5. Airspeed. Desired value is 100 knots. Same start/stop logic as Glidepath.

II. Special Data Card Scores

Range scores were computed by taking the absolute difference between the maximum and minimum values. Rotation speed during takeoff was the actual value recorded by the IP. Centerline deviation scores in the Straight-in Landing are dichotomous values (0 = Off; 1 = On). Altitude deviation while on glidepath was scored as the average absolute deviation from desired at 1.75, 1.5, and 1.25 NM.

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